Body Temperatures of Malaysian Rain Forest Mammals

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ABSTRACT: Rectal temperatures of 23 species of Malaysian mammals were recorded during the course of an intensive mark-recapture program in rain forest. Repeated capture allowed repetitive readings for many individuals over several months. Individual variations and group comparisons are tabulated and discussed. Comparisons are made with body temperatures of arctic and temperate mammals. It was concluded that mean temperature for all tropical mammals described in this study was lower than in higher latitude forms, but that comparisons, to be meaningful, should be restricted to equivalent taxonomic groups.

BODY TEMPERATURES of tropical mammals are poorly known. Most published records refer to single individuals of exotic groups not having counterparts in more northerly latitudes. Often temperature data are taken from animals held in captivity for long periods (particularly in zoos), and the reliability of such data from animals living in captive environments may be questioned. This paper reports the temperatures of 23 species of Malaysian mammals of four orders, many individuals of which were repeatedly captured and on which multiple readings were possible (Table 1).

Rodbard (1950) has suggested that the mean body temperature of mammals weighing less than 1 kg bears a simple and direct proportion to body weight. In an effective refutation, Morrison and Ryser (1952) point to an essentially constant mean body temperature in most mammals. These authors, along with Scholander et al. (1950) and Wislocki and Enders (1935), agree however that certain groups of mammals (notably the monotremes, marsupials, edentates, and chiropterans) either maintain a consistently low body temperature or show a great temperature lability. Moreover, but without supporting data, Morrison and Ryser (1952) point out the possibility that within certain selected homogeneous groups of good regulators body temperatures may be significantly different from the general mammalian norm of 37.8° C. The present paper illustrates such a condition, particularly in the comparisons of 11 species of sympatric murid rodents and of 4 species of sciurid rodents. Illustrated as well is individual variation in body temperatures and to a lesser extent behavioral relationships to temperature.

MATERIALS AND METHODS

All data derive from a single locality—Ulu Gombak, 20th mile Pahang Road, ½ mile NE Genting Simpah Youth Hostel, State of Selangor, Malaysia. The elevation at this location is about 1,900 ft. The climate in Malaya (about 3° N) is remarkably constant; the photoperiod varies only about 20 minutes over a year. Humidity and rainfall are generally high, although both daily and "seasonal" variations occur.

With the exception of the bats and of the single bamboo rat all mammals were taken in an area of 14 acres in primary and old secondary rain forest marked off in a trapping grid at intervals of 50 ft. For the entire trapping period (1 November 1963–22 May 1964) 225 live traps were maintained on the ground. In trees at varying heights small platforms were built on which traps were maintained, of which 50 were kept throughout the period and another 25 were added about halfway through. Normally traps were open four nights a week and were baited with coconut meat and banana. Trapped animals were brought each morning to a small shelter on the edge of the grid where temperature and other data were taken. Animals were then toe-clipped for individual identification, if not previously marked, and were returned to the station of capture for release. A total of 29,189 trap nights resulted in the

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capture of 377 individuals of 21 species with a total capture-recapture record of 2,616. Many individuals were recaptured five or more times. To minimize trauma of handling, temperatures were never taken oftener than once a week in frequently captured animals. Normally, however, the vagaries of recapture did not allow for temperature readings oftener than once every three or four weeks. A few additional temperature measurements came from individuals collected away from the grid area.

All temperatures were taken rectally with a Schultheis rapid-recording thermometer read to 0.1° C. Insertion of the entire bulb well past the lip of the column was simple enough for all but the smallest species (*Tylonycteris*). Even so, the temperatures recorded for this small bat are believed to be accurate. Data from obviously ill or moribund animals are not included in Table I. However, where these data might suggest critical temperatures they are included later in the discussion. There was no direct attempt to determine critical temperatures nor to determine metabolic responses to changing ambient temperatures. Confidence limits were calculated only when the sample constituted 10 or more individual readings.

RESULTS AND DISCUSSIONS

Individual Variation

Single healthy individuals irrespective of sex regularly varied within a two or three degree range over long periods of time. Yet the range on the temperature spectrum, while being consistent for individuals, often differed between them. Consistent behavioral differences seemed to correlate well with these individual patterns. The following tabulation shows repeated temperature readings of single individuals over many months. The individuals were selected because their behavior deviated sufficiently from the norm of the species to warrant mention in field notes. Only animals of the same sex and equivalent weigths are compared.

Rattus rajah

♂ Docile 36.5; 36.5; 35.1; 36.3; 35.5; 36.2; 37.8; 35.9; 36.8; 37.9; 36.4 ($\bar{x} =$ 36.44;; r = 35.1–37.9)

♂ Aggressive 36.4; 38.7; 38.9; 38.0 ($\bar{x} =$ 38.00; r = 36.4–38.9)

Rattus muelleri

♀ Docile 35.0; 35.4; 35.2; 35.8; 36.3 ($\bar{x} =$ 35.56; r = 35.0–36.3)

♀ Aggressive 37.8; 37.3; 38.6; 38.1; 38.1; 36.4 ($\bar{x} =$ 37.71; r = 36.4–38.6)

Rattus sabanus

♂ Docile 35.3; 36.1; 37.5; 35.2; 34.8; 36.3; 35.3; 37.4; 36.8; 36.5; 37.9 ($\bar{x} =$ 36.28; r = 34.8–37.9)

♂ Aggressive 36.6; 36.2; 37.3; 37.8; 37.5; 35.8; 39.2; 39.4; 38.4; 38.3 ($\bar{x} =$ 37.65; r = 35.8–39.4)

♀ Docile 36.6; 36.7; 36.8; 36.9; 36.2; 36.3; 34.8; 37.2 ($\bar{x} =$ 36.45; r = 34.8–37.2)

♀ Aggressive 35.2; 37.1; 37.4; 35.4; 37.1; 37.3; 36.1; 36.0; 38.0; 37.8; 38.2; 37.9; 38.9 ($\bar{x} =$ 37.10; r = 35.2–38.9)

In these instances mean temperature readings between individuals of like species, sex, and weight varied as much as 1.5° C. Yet, essential consistency characterized the body temperatures of these and most other individuals of groups generally regarded as having a high ability to regulate temperature. Only in one group other than rodents are repeated readings available. In the insectivore *Hylomys* the temperature range in individuals was slightly wider than in most rodents. One adult male with seven readings showed a variation of 2.8° C (33.6°–37.4°); an adult female with eight readings showed a variation of 3.0° (35.1°–38.1°).

The possible influence of the trapping regime on temperature was checked in 16 repeatedly taken individuals of four species of *Rattus*. Since trapping and handling procedures were standardized, it was assumed that individuals captured 20 or more times might become habituated and therefore show less variation in temperature. The first three and the last three temperature readings were graphed against body weight. Although changes in both measures occurred, in no case was there a consistent pattern of temperature change. The range of temperature remained as great after several months of trapping as at the beginning.

Relation of Temperature to Reproductive State and Sex

In the first weeks of trapping a few individuals showed signs of recent lactation. How-

TABLE 1

RECTAL TEMPERATURES OF 23 SPECIES OF MALAYSIAN RAIN FOREST MAMMALS*

SPECIES NAME	NO. OF INDIVIDUALS	NO. OF TEMP. READINGS	TEMPERATURE RANGE	MEAN ± 95% CONF. LIMITS	COEFFICIENT OF VARIABILITY
Insectivora					
Erinaceidae					
Hylomys suillus	14	34	33.6–38.1	36.11 ± 0.35	2.79
Echinosorex gymnura	2	2	28.1–32.3	30.20	—
Chiroptera					
Pteropidae					
Cynopterus brachyotis	3	3	34.0–36.3	35.33	—
Vespertilionidae					
Tylonycteris robustula	9	9	34.3–38.4	36.64	—
Primates					
Tupaiidae					
Tupaia glis	4	9	35.8–39.2	37.50	—
Tupaia minor	2	2	39.1;39.1	39.1	—
Lorisidae					
Nycticebus coucang	1	1	34.9	34.9	—
Rodentia					
Sciuridae					
Callosciurus caniceps	4	4	40.1–41.4	40.65	—
Callosciurus notatus	6	6	35.8–41.2	38.58	—
Callosciurus nigrovittatus	1	2	40.1;40.9	40.50	—
Sundasciurus tenuis	10	12	36.6–42.1	39.44 ± 1.13	4.59
Rhizomyidae					
Rhizomys sumatrensis	1	1	36.1	36.1	—
Muridae					
Rattus annandalei	2	12	36.1–38.2	37.10 ± 0.63	1.76
Rattus muelleri	26	79	34.5–39.2	37.04 ± 0.28	3.53
Rattus sabanus	157	670	33.7–39.4	36.54 ± 0.53	7.61
Rattus rajah	21	86	35.1–39.6	37.25 ± 0.58	7.32
Rattus surifer	55	138	34.4–39.3	37.40 ± 0.32	5.32
Rattus jalorensis	6	6	34.8–38.2	36.80	—
Rattus cremoriventer	9	16	36.2–39.7	38.20 ± 0.40	1.97
Rattus whiteheadi	19	36	35.8–39.2	37.91 ± 0.28	2.34
Rattus edwardsii	4	20	34.6–38.2	36.22 ± 0.48	2.89
Rattus bowersi	6	8	34.2–37.5	35.87	—
Chiropodomys gliroides	21	32	35.9–39.1	37.80 ± 0.35	2.59

* Scientific names follow Harrison and Traub (1950) and Medway (Mammals of Borneo, *in press*).

ever, throughout the majority of the period there was no other evidence of breeding. Therefore temperature readings recorded herein have to be considered applicable to nonbreeding animals.

Sexual differences in temperature were generally very small and were concluded to be insignificant. For this reason no sexual separations are made in Table 1. Curiously, however, in the sibling species pair, *Rattus rajah* and *R. surifer*, females consistently showed higher temperatures. In *R. rajah* mean temperatures of females were 1.3° higher than males; in *R. surifer* 0.5° higher. There is no ready explanation for these differences.

Relation of temperature to body weight

Irving and Krog (1954), Morrison and Ryser (1952), and Scholander et al. (1950) effectively show that mammalian body temperature bears no primary relationship to body weight. Rather consistent differences in temperature relate to the mammalian order and the adaptive habits of the species in question. With the exception of *Nycticebus* all 22 species described in this paper weigh less than 1 kg. Of these only one, *Echinosorex,* regularly exceeds 500 g. Its position as a primitive insectivore prompted me to remove it from comparison with the remaining species. To determine whether consistent temperature differences were apparent among these small mammals, four 125-g categories were created. The temperatures of animals of different species whose adult body size did not exceed 125 g were averaged to constitute the first class; those from 125–250g the second class, and so on. Mean results were as follows: Class I, 37.85°; Class II, 37.41°; Class III, 36.72°; Class IV, 35.87°. The last class included only one species (*R. bowersi*). Only the first class meets the mean value of 37.8° given by Morrison and Ryser (1952) as applicable to most mammals weighing under 1 kg. Differences between means are not as great as temperature differences displayed by individuals over periods of time. Nonetheless, there is a consistent decline in mean temperature as adult animal size increases. Most of the species included in the foregoing classes are rodents. About all one may conclude from these data is that no single figure precisely describes mean temperature values even among phylogenetically closely related forms.

Critical Internal Temperature

In the absence of experimental data critical temperatures can only be estimated by indirect means. Apparently a lowering of 4–5° from normal is the maximum tolerable drop. Records of three subadult male *Rattus sabanus* may illustrate. The first individual was heavily wetted and quiet at first capture but still in apparent good health. At this time its body temperature was 36.4°. In its next three captures the animal was very active and showed a mean temperature of 38.4° (38.0°–38.9°). A second individual, quiet but in good health on its first three captures, had a mean temperature of 35.9° (35.4–36.2). The animal was dry but obviously sickly on its fourth capture and at this time had a temperature of 31.3°. It was not subsequently recaptured. A third individual, heavily wetted and moribund at its first capture, had a body temperature of 31.4°. At its second capture six days later its temperature was 35.9°.

Comparisons of Groups

The mean temperature of all mammals in this study was 37.1°. Morrison and Ryser (1952) place the mean temperature of 56 species of mammals in the 15 g–700 kg range at 37.8°. Irving and Krog (1954) place the value at 38.6° for 22 species of arctic and subarctic forms. One might postulate a latitudinal relationship with temperature. Since, however, large and consistent differences in temperature exist between groups it seems more reasonable to compare only equivalent taxonomic units. The mean temperatures of five groups are listed below.

Insectivora	(2 sp.)	33.2°
Primates	(3 sp.)	37.2°
Chiroptera	(2 sp.)	36.0°
Rodentia		
Sciuridae	(4 sp.)	39.8°
Muridae	(11 sp.)	37.1°

In these instances it is clear that a single mean value cannot meaningfully represent the "typical" body temperature of a tropical mammal. Moreover, different species within these groups often consistently differ. The two gymnures differ markedly, for example, and both differ from soricine insectivores (Morrison and Ryser, 1952). *Tupaia* has "squirrel-like" temperatures rather than the somewhat lower values found in other primates. The sciurids maintain a consistent "above average" temperature in relation to most mammals (as noted also in Irving and Krog, 1954 and Spector, 1956). Even among murid rodents mean values of the smaller species are 2° higher than the largest (*Rattus bowersi*). The need to consider the adaptive requirements of the particular group seems obvious. How to judge what these adaptive requirements are is, of course, a more difficult task.

ACKNOWLEDGMENTS

Field investigations in Malaysia were supported by National Institutes of Health Research Grant GM 11121-01. I acknowledge with particular thanks the help of my assistants, Mr. Ngeow Poh Wah in Malaysia, and Mr. Gary L. Stevens in the United States.

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